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STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

WELDING OF LARGE SIZE REINFORCING BARS

MANUAL OF INSPECTION WITH RADIOGRAPHIC REFERENCE

58-11

1958

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TABLE OF CONTENTS

GENERAL NOTES ON THERMIT WELDING OF LARGE SIZE REINFORCING BARS.

1. Procedure tests will be required for all thermit welding. The methods, materials, and chemical proportions used in the actual thermit welding shall conform to those tested and approved in the procedure tests.

2. Reinforcing bar edge preparation shall be a square cut either by oxyacetylene or saw cut as outlined in the thermit welding report. (See Exhibit 1, pictures 1, 2, 3 and 4, showing preparation of the reinforcing bars).

3. Where moisture may collect either in the thermit molds or on the reinforcing bars, the weld area of the reinforcing bars shall be preheated to 400 F. The thermit mold shall also be preheated to a temperature not less than 250°F before igniting the thermit.

4. Preheating of the reinforcing bar can be performed after the thermit mold is clamped in place and luted, by heating the reinforcing bars to 600°F at a distance of 2" to 4" from the luting area.

5. The thermit compound, molds, and thermit starter compound shall be stored in a dry place. The thermit compound shall not be stored with the thermit starter compound. All thermit compounds shall be kept dry as moisture in the thermit compound will cause gas inclusions and porosity.

6. The luting sand should have just sufficient moisture to properly bind the sand.

7. When thermit welds are rejected and repairs are necessary, the defective area shall be removed and the repairs may be performed by the manual welding process using E7016 low hydrogen electrodes. (See Manual Welding)

8. Preheating of thermit welds promotes greater toughness, and ductility, and lessens porosity and gas inclusions in the joint. If preheating is included in the prequalification tests, then a preheat of 600°F (from previous test) can be employed to insure greater toughness and ductility.

9. Control of preheating can be effected by use of temperature crayons, e.g. Tempil Sticks.

10. The time necessary for the preparation and welding of a joint requires 15 to 30 minutes, depending on the location of the joint.

11. Quality inspection should be maintained at all times where thermit welding or manual welding is being performed.

12. Radiographic inspection can be used as a quality control. (See Radiographic Inspection).

THERMIT WELDING OF REINFORCING BAR-PROCEDURE TESTS

Procedure Specimens

Four test specimens shall be submitted of welds made in each welding position which are to be employed in the construction, and these tests shall employ the same methods and chemical proportions that are to be employed during construction.

All specimens shall be subjected to full size tension tests.

Test Results

All weld test specimens shall attain at least the specified proportional strength of the reinforcing bar to be employed.

Retests

Each weld test failing to meet the minimum test results shall require two new samples to be submitted for retest, each of which must comply with the requirements outlined under "Test Results".

Specimen Size

Each specimen submitted shall have an overall minimum length of 36", and the center of the weld area shall be at least 18" from each end of the bar.

THERMIT WELDING OF LARGE SIZE REINFORCING BARS

(Techniques and Procedures)

A. Preparation of the Reinforcing Bars

The reinforcing bars to be thermit welded require proper preparation. The ends of the reinforcing bars should be squared off either by use of an oxyacetylene cutting torch, sawing, or by some suitable mechanical method. It is very important to insure square ends of the reinforcing bars, and to remove all sheared edges which may have been fractured during shearing operations.

The following points should be observed when employing oxyacetylene cutting for end preparation.

(a) The oxyacetylene cut reinforcing bar should be as squarely cut as possible and be not more than 1/8" out of square.

(b) The oxyacetylene cutting tips and oxyacetylene working pressures should be so adjusted to produce a clean cut as can be seen in (Exhibit 1), pictures 1 and 2. Pictures 3 and 4 are examples of defective cuts which should not be employed without either grinding the face smooth or recutting.

(c) Dirt, oxide scale, oil, or grease, or other foreign matter should be removed from the area covered by the thermit mold.

B. Alignment of Reinforcing Bars

The reinforcing bars should be properly aligned and held securely in position; a gap of approximately 3/8" of an inch is maintained and measured by means of aligning bar as can be seen in (Exhibit 2), pictures 1, 2, and 3.

C. Placing of the Thermit Mold

Once the reinforcing bars are properly aligned and securely held by some suitable means, the thermit mold can be installed with half of the mold on each side of the reinforcing bar at the weld area. The thermit molds are held together with "C" clamps or bolts, whichever is recommended by the supplier.

The aligning rod is then inserted into the mold through the center hole or tapping gate of the mold and then through the gap between the reinforcing bars until the aligning rod is seated. The aligning rod serves the purpose of centering the thermit molds tapping gate over the reinforcing rod gap. (CAUTION) If centering is not performed correctly improper fusion in the weld center of the reinforcing bar may occur. (Exhibit 3), pictures 1, 2, and 3.

D. Luting the Thermit Mold

The luting of the thermit mold is shown in (Exhibit 4), pictures 1, 2, and 3. This is accomplished by packing the flares about the rods as shown, with molding sand, finger compaction is employed to completely fill the flared sections of the thermit mold and is finished off with a good fillet of packed sand around the edge of the mold.

It is very important that the luting be done carefully and thoroughly in order to avoid leakage or break-through of the molten metal through the space between the mold and the reinforcing bar during the tapping or pouring operation of the molten metal.

E. Removing Aligning Rod, Placing of Tapping Disc, and Placing of Thermit into Mold Crucible

When the mold is in place and properly fastened, the aligning rod is removed and the first tapping disc is placed into the seat in the bottom of the mold. This disc is tamped lightly in order to seat it. The second disc is dropped into place and likewise lightly tapped so as to seat firmly over the first disc.

The thermit mixture is then poured into the mold and leveled off by hand (CAUTION). Be sure that the same type of thermit is used as was furnished for the procedure test and approved. The type of thermit mixture is always stamped or tagged on the bag. Do not allow split or partial portions of a bag of thermit. Thermit should be stored in a dry place away from sparks and fire. (See Exhibit 5), pictures 1, 2, and 3.

F. Igniting the Thermit Weld

A small charge (approximately one teaspoon full) of starting thermit is placed on the top center of the thermit mixture. (CAUTION) The starting thermit is highly flammable and lighted cigarettes, matches, or sparks will readily ignite it.

A flint lighter is recommended to ignite the starting thermit. The lighter is held very close and struck until the sparks ignite the starting thermit. This starter in turn ignites the main thermit charge. The reaction takes place in approximately 25 seconds, producing white hot metal with slag floating above the charge. Shortly after the reaction reaches completion, the superheated steel melts through the tapping disc and flows into the lower area of the mold, washing the square cut ends of the reinforcing bars with molten metal, with the superheated steel producing fusion of the reinforcing steel bars. The slag remains in the upper part of the mold crucible. (See Exhibit 6), pictures 1, 2, and 3.

G. Stripping the Mold

It requires approximately 30 minutes after ignition for all the weld metal and slag to solidify. It is then possible to remove the mold from the reinforcing bar weld.

It will do no harm for the mold to be left on the weld for a longer period of time. However, it is not advisable to take the mold off the reinforcing bar weld in less than 30 minutes, as all of the weld metal may not be solidified, and chilling at this critical temperature may damage the weld or metal structure.

The tapping gate reservoir risers can be broken off from the thermit welds with a hammer when cool, or cut off with an oxyacetylene torch so that the completed weld is as shown in (Exhibit 7), pictures 1, 2, and 3.

H. Thermit Welding up to and Including a 25° Angle

The horizontal thermit molds were tilted during test up to a 25° angle and a satisfactory thermit weld made. (See Exhibit 8) for details.

I. Vertical Thermit Welding

Vertical thermit welds are made in the same manner as a horizontal thermit weld except for the modifications in aligning procedure of the thermit mold to the reinforcing bars. (See Exhibit 9 for details).

J. Vertical Welding Number 18 size Reinforcing Bar to Number 11 Reinforcing Bars

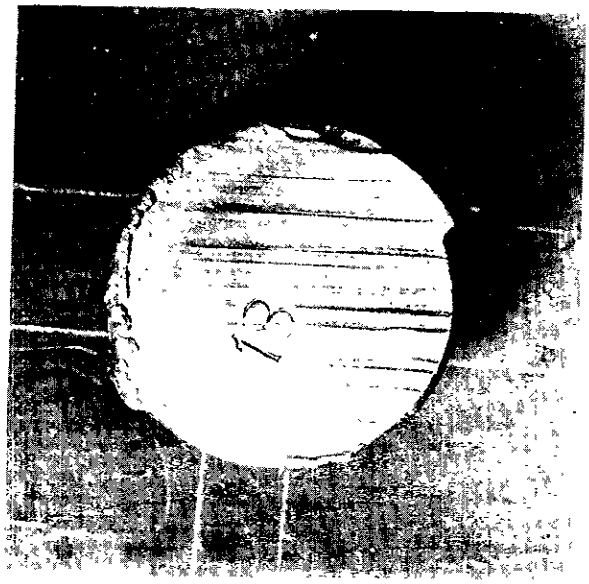
The welding of number 18 reinforcing bars to number 11 reinforcing bars has been performed by using the number 18 reinforcing bar thermit mold. This was accomplished by making a reducer of foundry sand fit into the top half of the thermit mold (See Exhibit 10).

The thermit charge employed was the same as for making a full number 18 reinforcing bar weld. The reinforcing bar alignment and gap spacing are the same as employed for a vertical thermit weld using number 18 reinforcing bars.

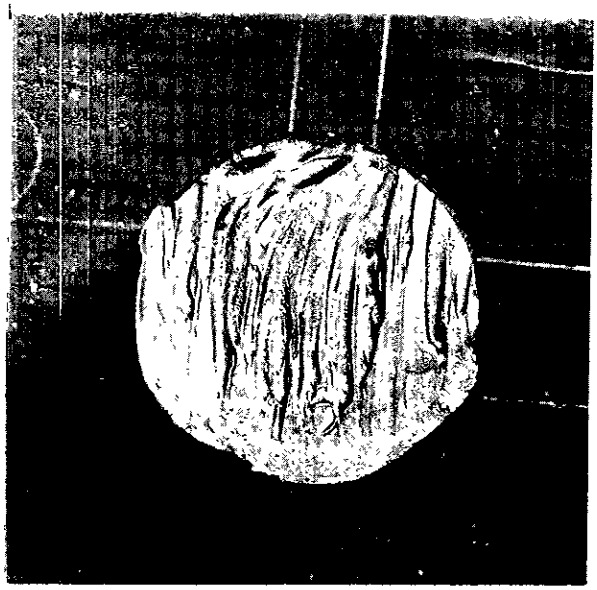
K. Thermit Welding Hazards

All personnel having any duties in connection with thermit welding operations should be careful while working in or around such welding during fabrication and erection.

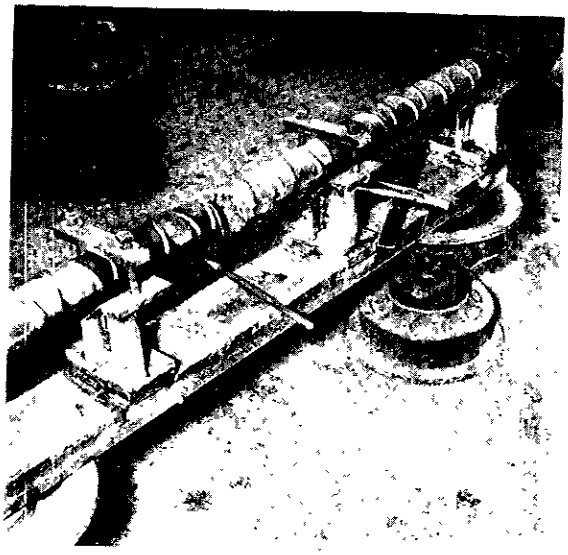
Failure of the luting sand will permit white hot metal to flow out of the mold. This super-heated steel will burn through sheet iron, steel, or wooden planking, so precautions should be taken for personnel safety.



Pictures 1 and 2 represent acceptable oxyacetylene cut reinforcing bars. If the cut is rougher than picture 2, the direction of cut should run in the direction of the thermit metal flow or wash.



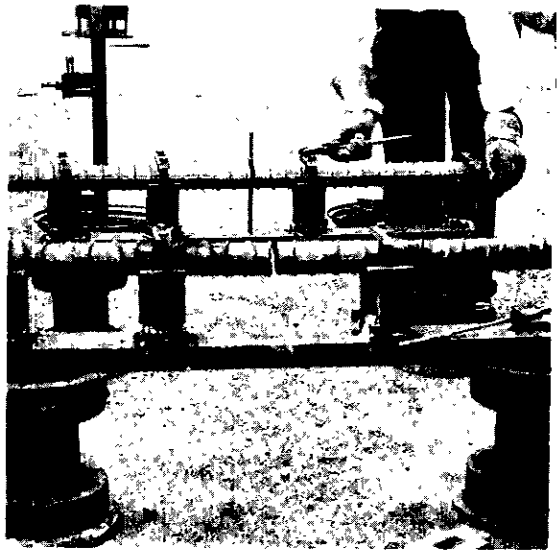
Pictures 3 and 4 are defective cuts and should not be used. Such cuts must be ground smooth or recut.



Picture 1

<u>The aligning and spacing of the reinforcing bars.</u>

Where possible, the longitudinal deformation of the reinforcing bars should be in line. This is to eliminate possible offsetting of the reinforcing bars. Picture #1 shows the longitudinal deformations.

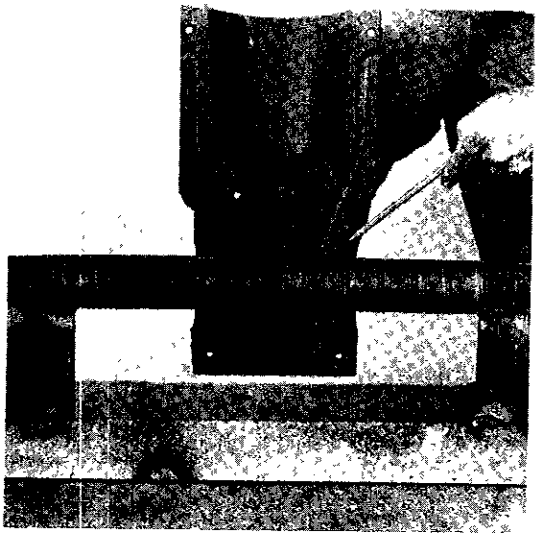


Picture 2

The reinforcing bars must be properly aligned and held in position. A gap of approximately 3/8" is measured by means of an aligning bar. This aligning bar is also used to align the thermit mold with the spacing of the reinforcing bars.

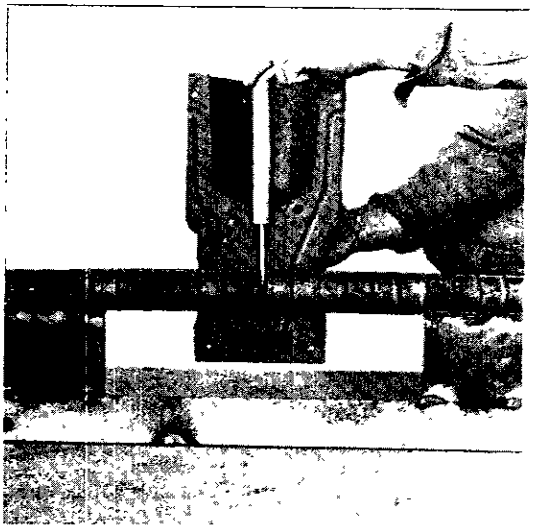
Picture 3

Vertical reinforcing bars require the same care in aligning and spacing as horizontal reinforcing bars. This photo shows the spacing and aligning of a #18 reinforcing bar to be thermit welded to a #11 reinforcing bar.



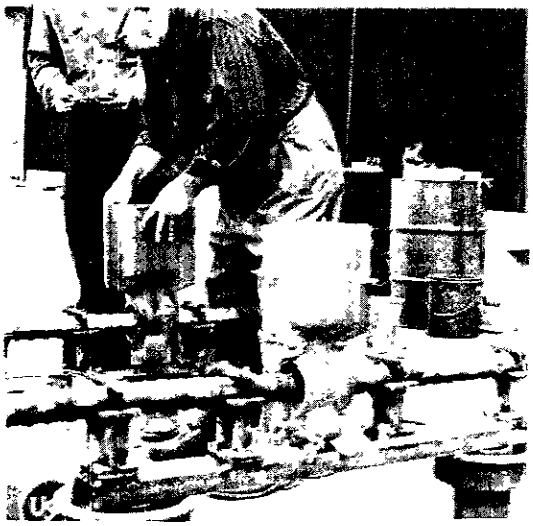
Picture 1

The placing of the thermit molds is accomplished after the reinforcing bars are aligned and securely held. The thermit mold is arranged with half sections on each side of the reinforcing bar weld area.



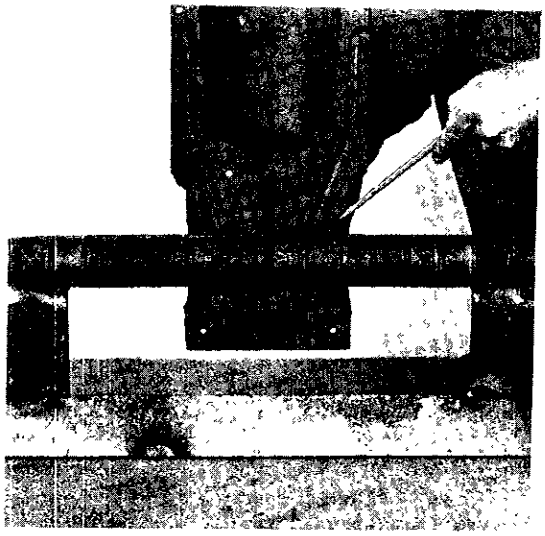
Picture 2

An aligning rod is inserted into the thermit mold as shown. This is to insure alignment of the tapping gate to the reinforcing bar spacing.



Picture 3

The thermit mold is then clamped onto the properly aligned and spaced reinforcing bars.



LUTING THE THERMIT MOLD

Picture 1

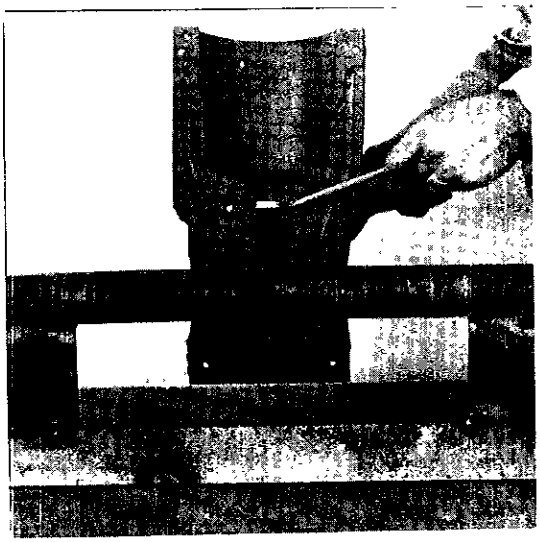
The thermit mold should be centered concentrically on the reinforcing bars so an even weld collar or flashing will be maintained around the bars.
The flared section shown here is packed with luting sand.

Picture 2

Be sure to pack the luting sand carefully with the fingers into the flared sections of the thermit mold.

Picture 3

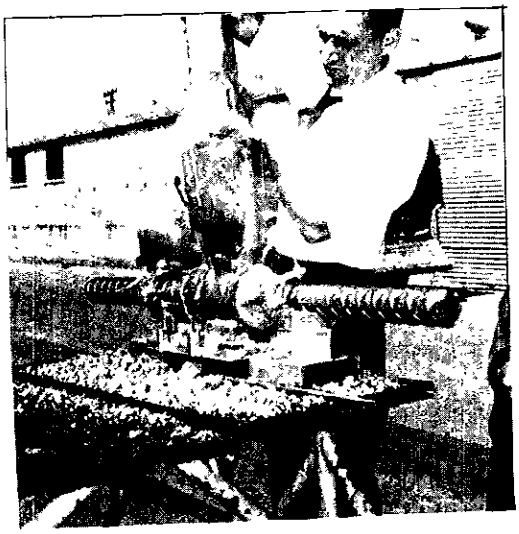
After thermit mold is properly packed with luting sand, the aligning rod is removed and the tapping discs placed in the mold.



REMOVING ALIGNING ROD, PLACEMENT OF TAPPING DISCS, AND PLACING OF THERMIT INTO MOLD CRUCIBLE

Picture 1

The location of the two tapping discs is shown here. The tapping discs will not properly seat in the bottom of the upper part of the mold-well without tamping them lightly. Care is exercised when tamping the discs so as not to damage the mold.



Picture 2

The thermit mixture, properly identified, is then poured into the thermit mold as shown here.

Picture 3

The thermit mixture is then leveled off, usually by hand and a small amount (approximately one teaspoon full) of starting thermit is placed at the top center of the thermit mixture.

THE THERMIT WELD

Picture 1

A flint lighter is used to ignite the starting thermit as shown here. The lighter is held very close and struck until the sparks ignite the starting thermit.

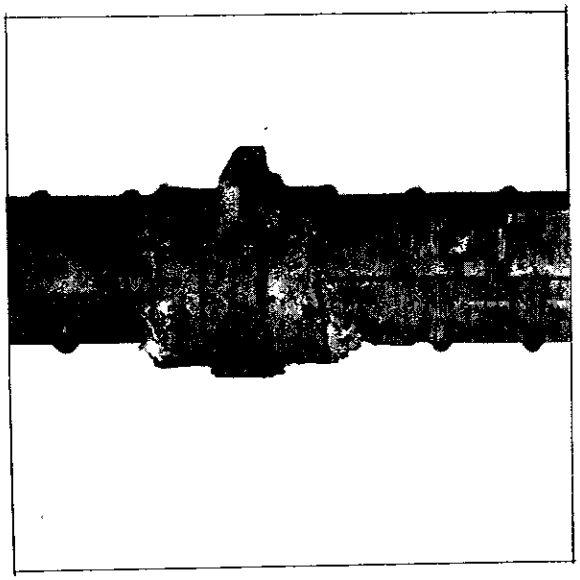
Pictures 2 and 3

A typical horizontal (picture 2) and vertical (picture 3) thermit weld reaction can be seen with molten metal splashing onto the ground.

Precautions should be taken in regard to personnel safety and the burning of concrete forms, etc.

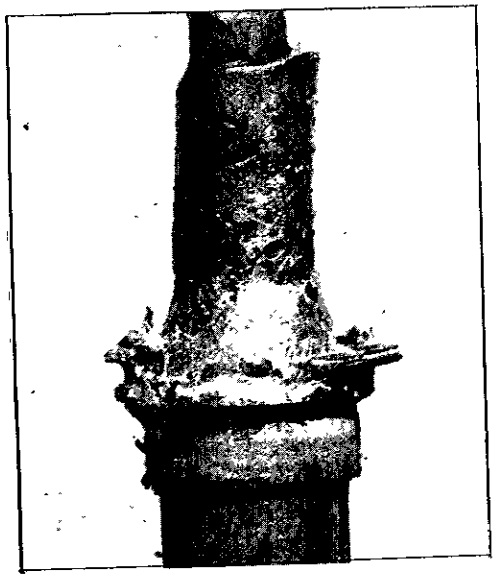
Picture 1

The tapping gate and reservoir can be broken off with a hammer after the weld cools to leave the completed weld as shown here.



Picture 2

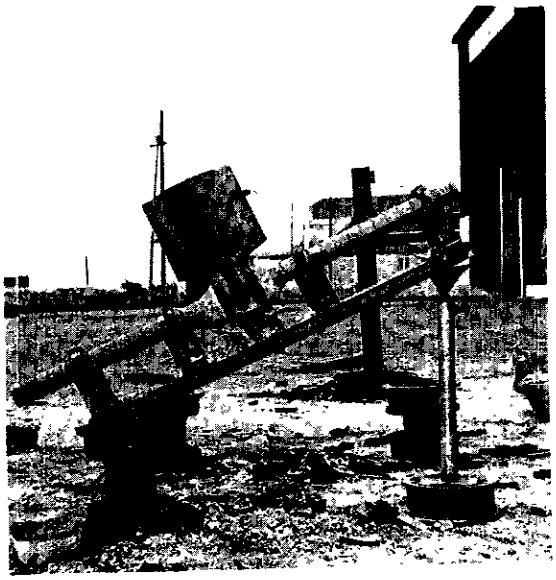
Close up view of a horizontal thermit weld (same as picture number 1).



Picture 3

Close up view of a number 18 reinforcing bar welded to a number 11 reinforcing bar with tapping gate and reservoir broken off.

THERMIT WEIDING UP TO AND INCLUDING A 25° ANGLE



This shows a horizontal thermit mold tilted to a 25° angle and a satisfactory thermit weld made.

The placing of the molds and spacing of the reinforcing bars is the same as for horizontal thermit welding.

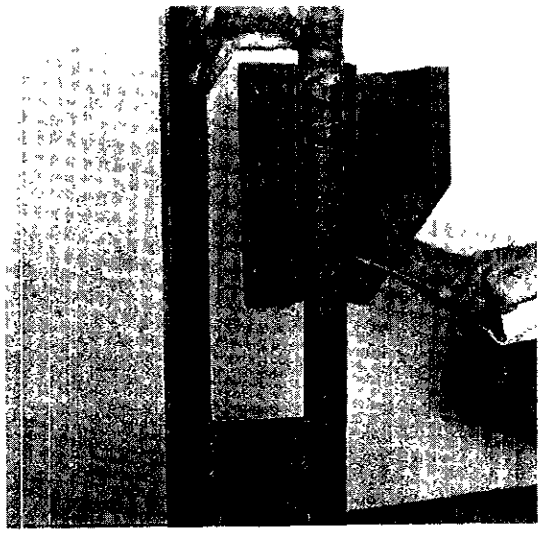
Under such conditions the mold must be secured into position. Here wires are attached from the thermit mold clamps to the reinforcing bars in order to hold thermit mold in place.

VERTICAL THERMIT WELDING

Picture 1

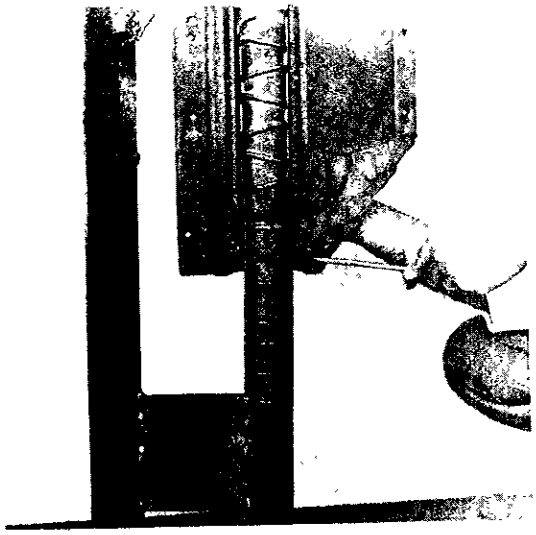
Showing the spacing and aligning of vertical reinforcing bars. The 3/8" spacing rod between the gap of the reinforcing bars can be seen here.

This procedure is the same as the aligning of horizontal reinforcing.



Picture 2

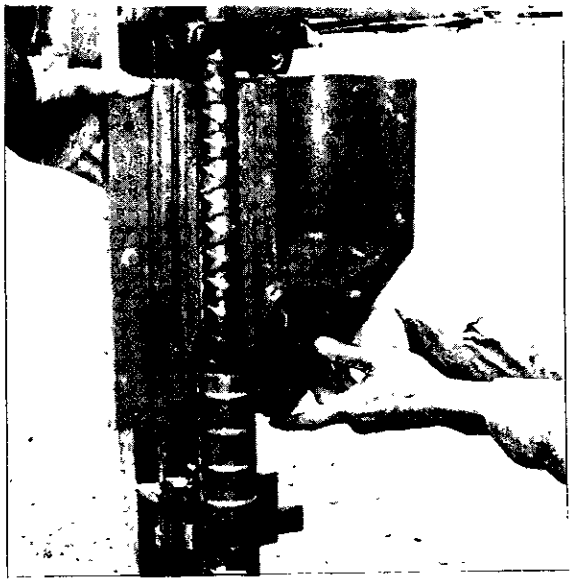
The first half of the vertical thermit mold is placed and aligned to the reinforcing bar gap by eye. The tapping gate and reservoir are as shown in the picture. (NOTE) A bracket must be attached to the reinforcing bar to hold thermit mold in position.



Picture 3

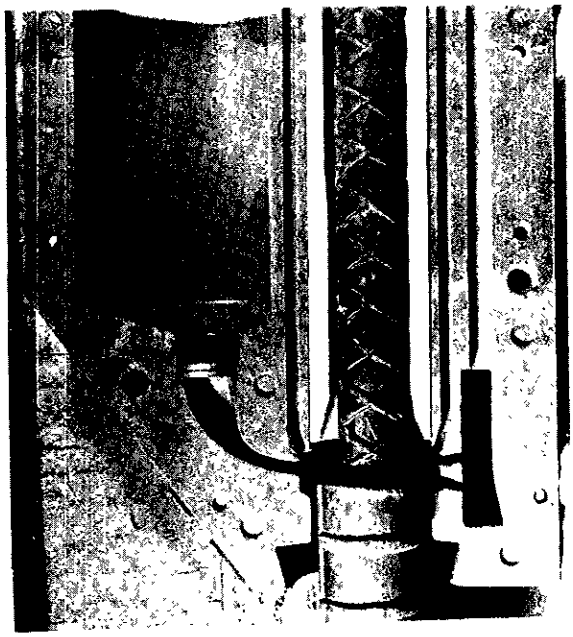
The thermit mold is then packed with luting sand, filling the mold flares shown here.

(J) VERTICAL WELDING NUMBER 18 SIZE REINFORCING BAR TO NUMBER 11 REINFORCING BARS



Picture 1

First half of the vertical thermit mold placed on a number 18 bar and matched to number 11 bar with reducer in place on the number 11 bar.



Picture 2

Close up view showing the reducer made of foundry sand. (Reducer is the white area around the #11 reinforcing bar.)

MANUAL WELDING
OF LARGE SIZE
REINFORCING BARS

GENERAL MANUAL WELDING NOTES

MANUAL WELDING OF LARGE SIZE REINFORCING BARS, 2" or #18

Because of the high carbon content (0.30% to 0.60% for intermediate grade reinforcing steel and over 0.60% for hard grade), preheating, controlled cooling and the use of low hydrogen electrodes are necessary for satisfactory results.

Preheating to 400°F for a distance of 6 to 12 inches on both sides of the joint is recommended.

For adverse conditions, post heating may be necessary. For normal conditions, wrapping the weld with a protecting blanket is adequate for obtaining the desired ductility.

PREPARATION:

The proper joint preparation of the reinforcing bar is essential to maintain a specified joint efficiency. The end preparation used should be such as to produce complete fusion with 100% penetration of the butt joint.

WELDS OF SMALL SIZE REINFORCING BARS BELOW NUMBER 7

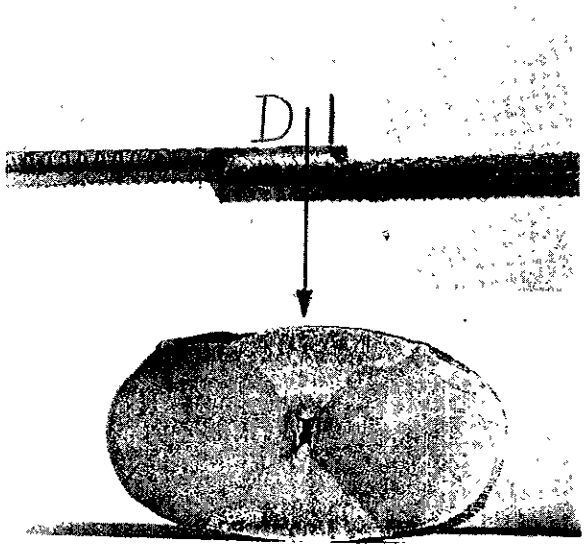
Reinforcing bars below #7 should not be butt welded. Reinforcing bars below #7 should be lap spliced; the lap splices should be made by fillet welds on both sides of the surface of the bars in contact with a minimum length of five inches of fillet weld. (See Exhibit 11)

MANUAL WELDING ELECTRODES

Reinforcing steel is classed as a hard to weld steel because of the unfavorable chemical composition and small cross section. Such steel requires the use of low hydrogen type electrodes.

The recommended electrodes to be employed for the welding of intermediate grade reinforcing steel are class E7016 or E7015 low hydrogen electrodes.

The care of these electrodes should be as outlined in test method No. Calif. 601-B.



Lap Weld Splice

Cut cross section to show weld area and contour.

Reinforcing bar below #7 should be lap spliced by manual welding using low hydrogen electrodes. A minimum length of five inches of fillet weld should be employed to develop the full strength of the reinforcing bar.

MANUAL WELDING PROCEDURE TESTS

Two procedure welding tests shall be made on reinforcing bars of the same size and grade of reinforcing steel as are to be used in the structure. The designated welding procedures, electrodes and joint preparation shall be employed.

TEST TYPE

All specimens will be subjected to full size tension tests.

TEST RESULTS

All weld specimens shall exhibit not less than the specified proportional strength requirements of the reinforcing bar grade to be welded.

RETESTS

For each weld failing to meet the minimum test results, two new samples must be submitted for test, each of which must meet the requirement outlined under test results.

SPECIMEN SIZE

Each specimen submitted shall have an overall length of at least 36", and the end of each bar shall be at least 18" long as measured from the center of the weld area to the end of the bar.

MANUAL WELDER QUALIFICATION TEST

The manual welder qualification test shall conform to the requirements of the "Standard Specifications for Welded Highway and Railway Bridges" of the American Welding Society, 1956, D2.0-56 Part II, Welder Qualification, with the following revisions:

BUTT WELD QUALIFICATION

Butt welds shall be made on the maximum 1" plate, using the low hydrogen electrode class E7016 or E7015.

RADIOGRAPHIC INSPECTION

RADIOGRAPHIC INSPECTION

Once the procedure has been set up and is being properly executed on the project, visual inspection is usually accepted as adequate for checking soundness of welds on reinforcing bars.

Radiographic inspection may be employed for quality control on any reinforcing bar welds.

The number of radiographs necessary to maintain good quality control will usually not exceed more than 10% of the total welds on the project. This 10 per cent control can be increased or decreased depending on the variable encountered. These variables can be recognized or established by visual inspection, depending on (1) the inspector's or engineer's knowledge of welding process used, and (2) adherence by the welding operator to the previously tested and approved procedures.

Any technique or procedure which will determine the quality of the welds is of prime importance and should be utilized to the greatest extent to supplement visual inspection. Radiographs are particularly valuable for detecting the following subsurface defects:

(1) Weld metal and base metal cracking

(2) Lack of penetration

(3) Incomplete fusion or lack of fusion

(4) Excessive slag inclusions

(5) Excessive porosity

Radiographs will also show the following surface defects:

(1) Undercutting

(2) Undersize welding

HAZARDS

All personnel having any duties in connection with, or in the vicinity of radiographic equipment, must avoid excessive exposure to radiation in accordance with the appropriate safety regulations.

PROCEDURES

These methods describe the procedures employed for X-ray and gamma ray inspection of welds made during construction.

1. The radiographic procedure, equipment, and materials shall conform to commercial practices currently accepted for the work.

2. Radiographs shall be made either by X-ray or gamma ray.

3. The radiographs shall be clear and of good workmanship. One or more penetrometers shall be employed as directed by the State.

4. Radiographic operators shall be experienced and capable personnel and shall perform their work in accordance with good practice and all safety regulations.

5. A report interpreting the radiographs shall be submitted to the inspector.

6. Radiographic inspection shall be scheduled and performed in such a manner as to reduce any interference with regular construction operations to a minimum.

7. Films shall be developed at the site of construction when so required.

8. All welding operators who are to make butt welds on structural or reinforcing steel which is to carry primary stresses shall be qualified by radiographic tests of their welding, in addition to other qualification tests required by the State. The radiographic test may be made on the welder qualification test plates and/or procedure test plates.

9. Welders shall be requalified by check tests, including radiographic tests, whenever the State deems it necessary.

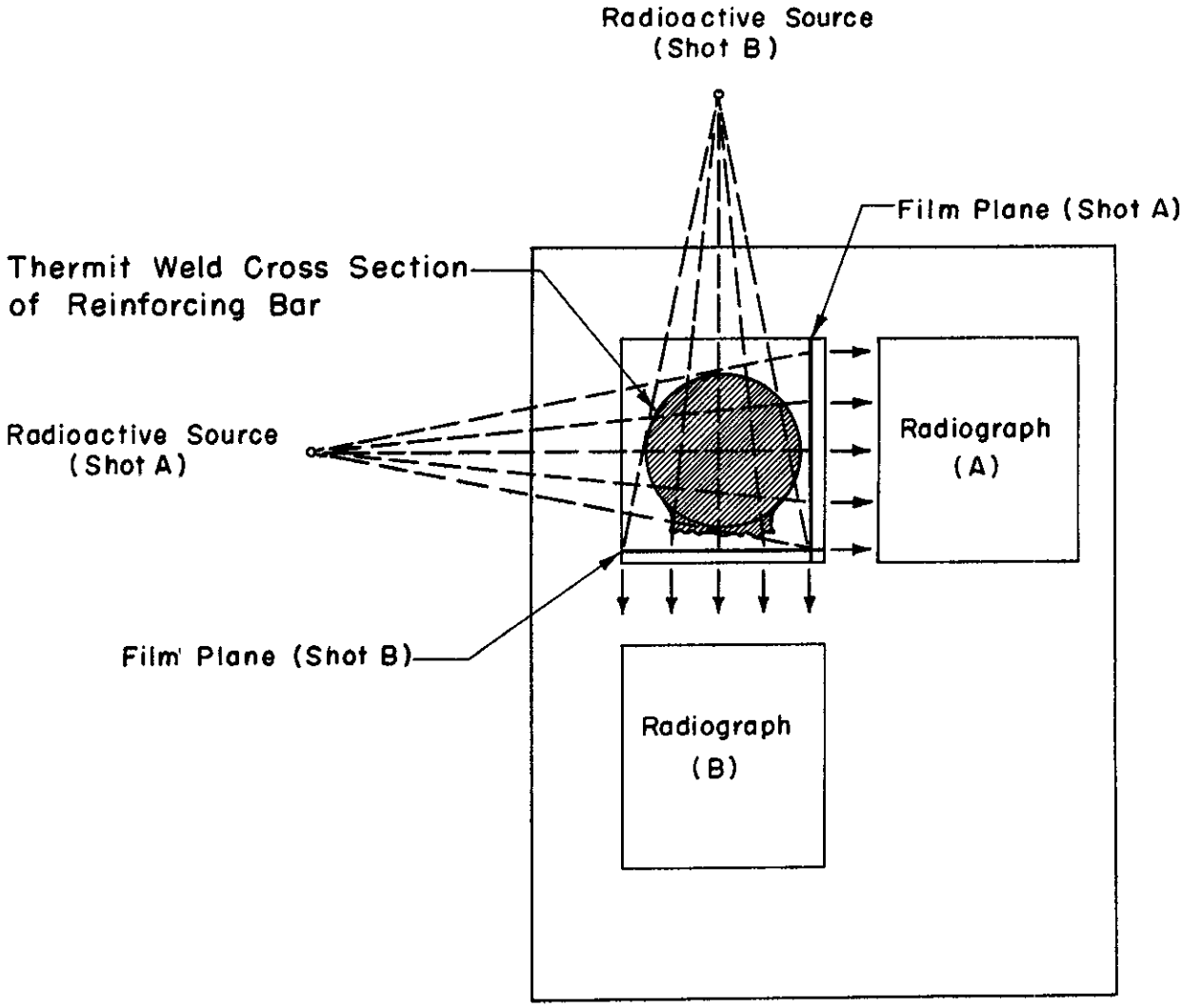
10. Radiographic films of the weld will be shown and interpreted to the welding supervisor. Welding operators should also view the radiographs of their respective work.

11. All work which is to be radiographed must be laid out in advance of the radiographic inspection and so arranged that interference with construction activities will be kept to a minimum.

12. Sensitivity

The weld shall be radiographed with a technique which will determine quantitatively the size of all defects with thickness equal to the standard sensitivity of 2 percent as based upon the thickness of the base metal.

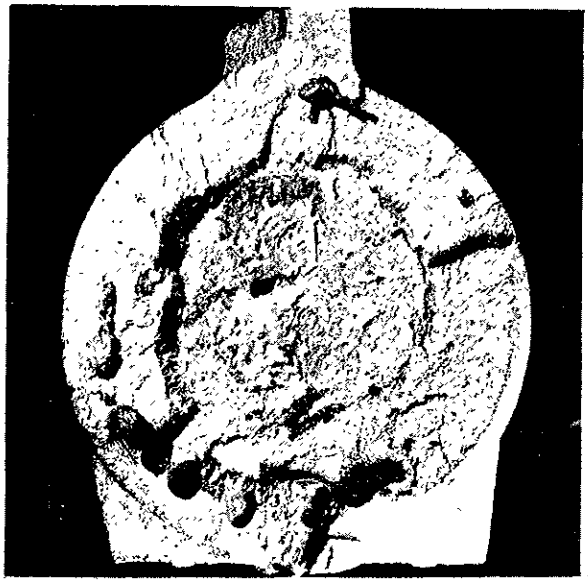
As a check on the radiographic technique, suitable thickness gauges or penetrometers shall be employed. The material of the penetrometer shall be substantially the same as that of the plate under examination.



TYPICAL PAGE LAYOUT WITH DIAGRAM
OF POSITIONING OF SOURCE FOR
RADIOGRAPHS

Exhibits 12, 13 and 14 illustrate unacceptable thermit welds through lack of fusion, excessive porosity and slag inclusions.

UNACCEPTABLE THERMIT WELD



Section Through Weld #1

Gamma Radiograph (a)

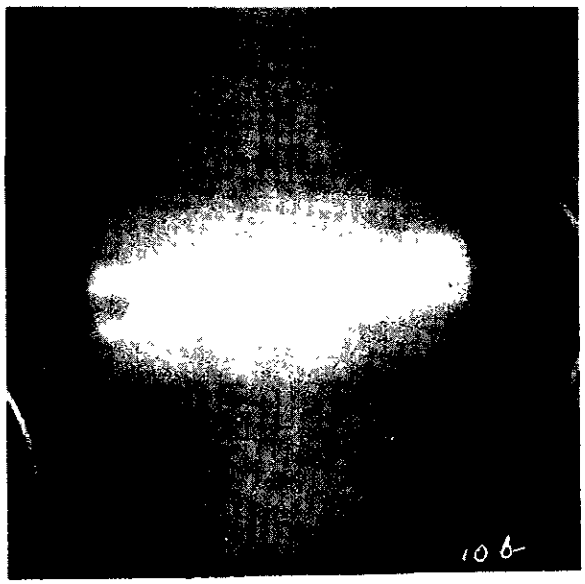
Gamma Radiograph (b)

Lack of fusion and excessive porosity in an unacceptable thermit weld, probably caused by moisture from the luting sand or by moisture absorbed from the surface of the bar, the mold, or the thermit. Such moisture is not visible, but it could prevent the liquid metal from properly wetting the bar ends. This defect could be eliminated (except in the luting sand) by mild heat (above 212°F) prior to welding. Similar defects could also be caused by rough bar ends. This prevents the liquid metal from washing the entire end surface of the bar. Smoother flame cutting or grinding would prevent this.

UNACCEPTABLE THERMIT WELD

Section Through Weld (10)

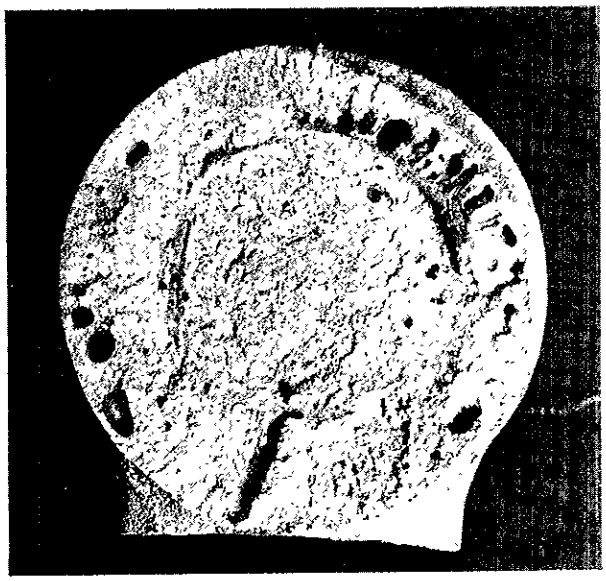
Gamma Radiograph (a)



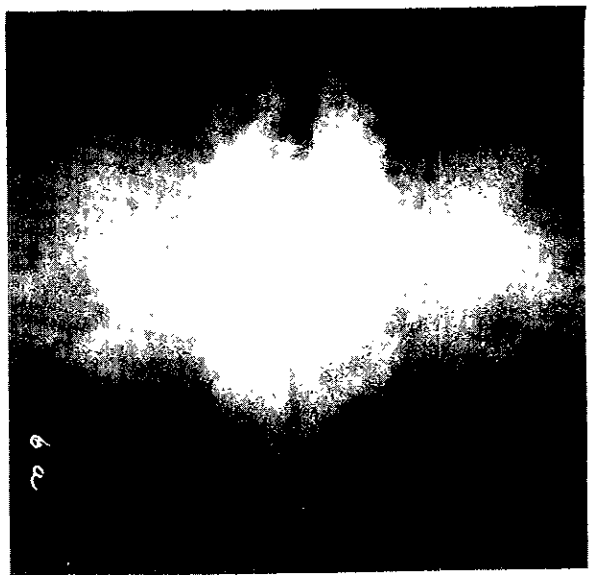
Gamma Radiograph (b)

Illustration of porosity, lack of fusion, and lack of penetration.

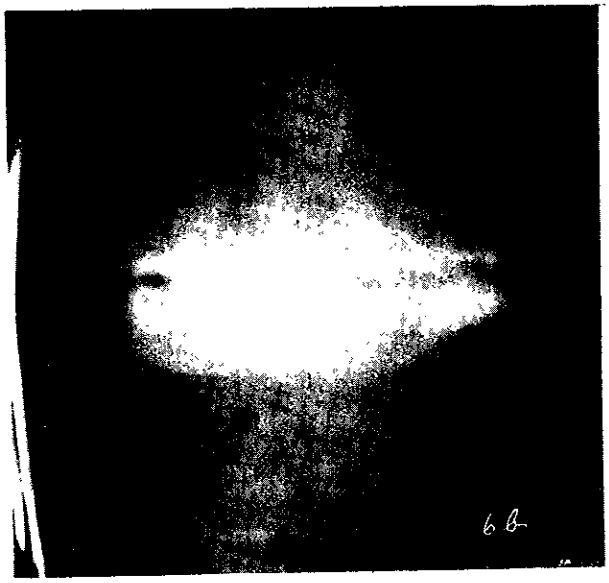
UNACCEPTABLE THERMIT



Section Through Weld (6)



Gamma Radiograph (a)

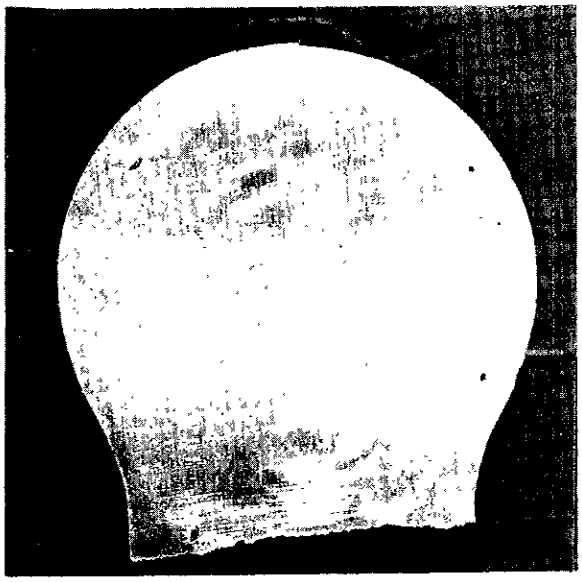


Gamma Radiograph (b)

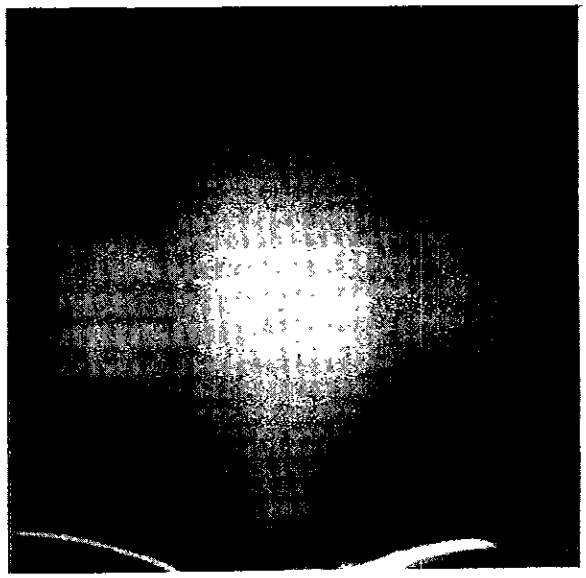
Illustration of porosity, lack of fusion, and lack of penetration.

Exhibits 15 through 19 illustrate the varying degrees of permissible porosity starting with the least permissible, Exhibit 15, and proceeding through the following exhibits in order of increasing severity of porosity.

ACCEPTABLE THERMIT WELD



Cross-section of Weld



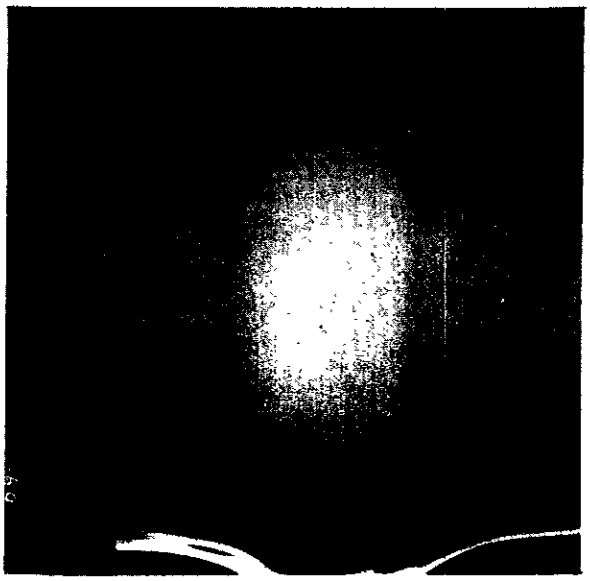
Gamma Radiograph (a)

Gamma Radiograph (b)

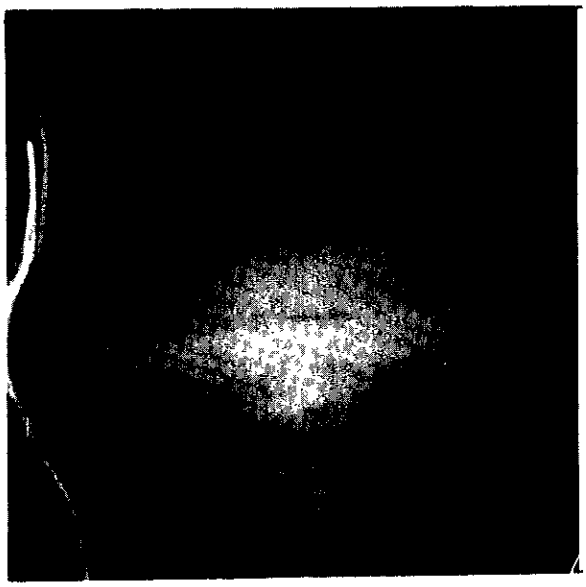
A sound thermit weld devoid of porosity. This condition can be promoted by preheating the bar just outside the mold such that the bar ends within the mold are heated by conduction. This preheating eliminates absorbed moisture and slows the solidification time sufficiently to permit gases and slag to escape from the melt. Note absence of porosity in radiographs and picture. Slowing the cooling after the solidification preheat also promotes a greater toughness and ductility in the joint.

ACCEPTABLE THERMIT WELD

Section Through Weld #16



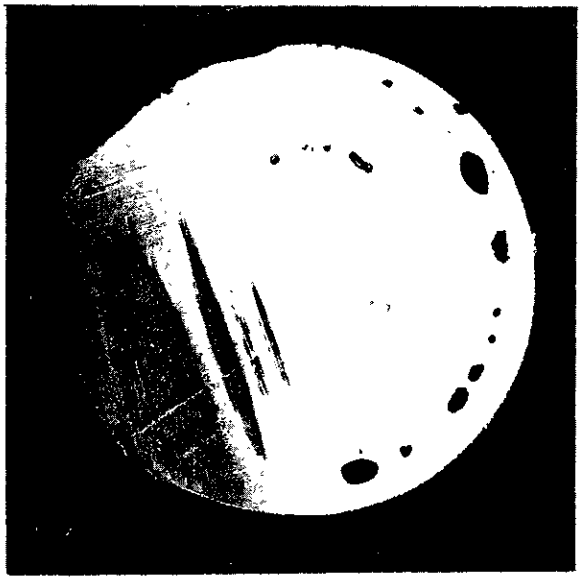
Gamma Radiograph (a)



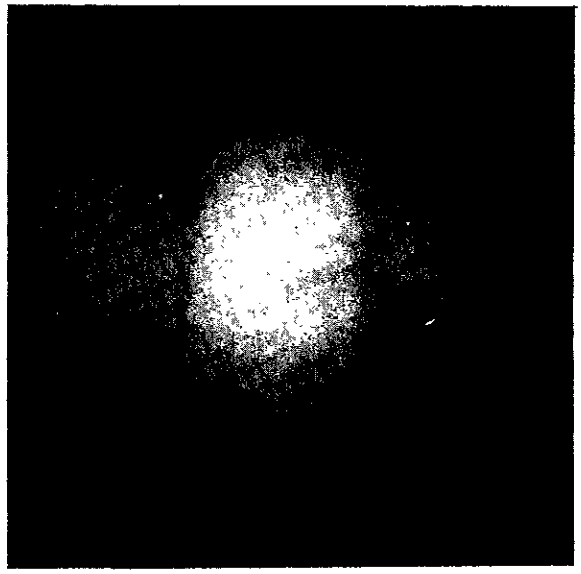
Gamma Radiograph (b

SLIGHT POROSITY

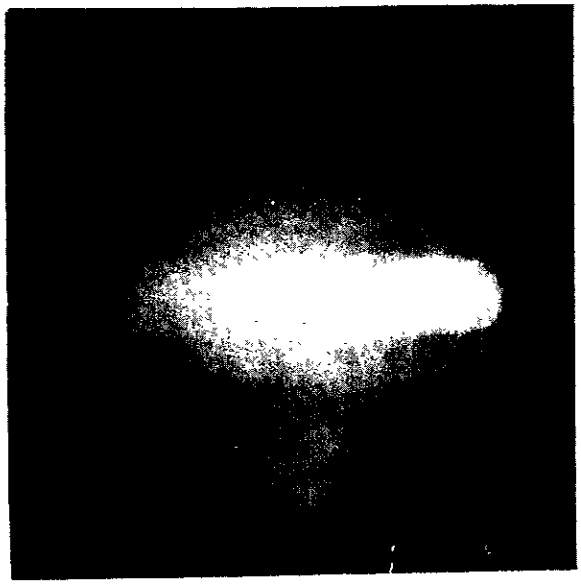
ACCEPTABLE THERMIT WELD



Section Through Weld #2



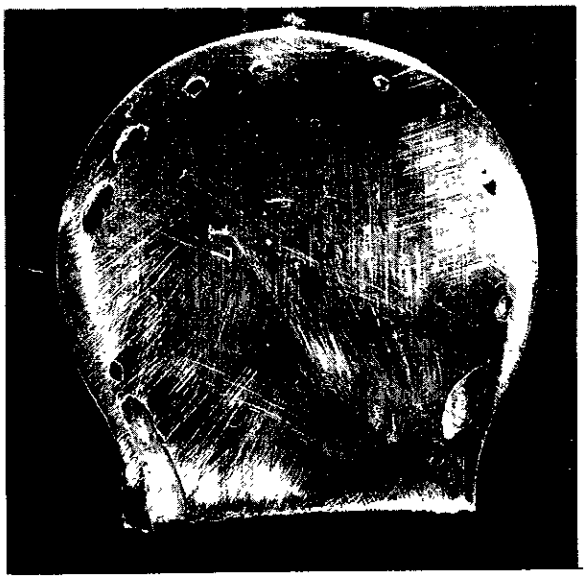
Gamma Radiograph (a)



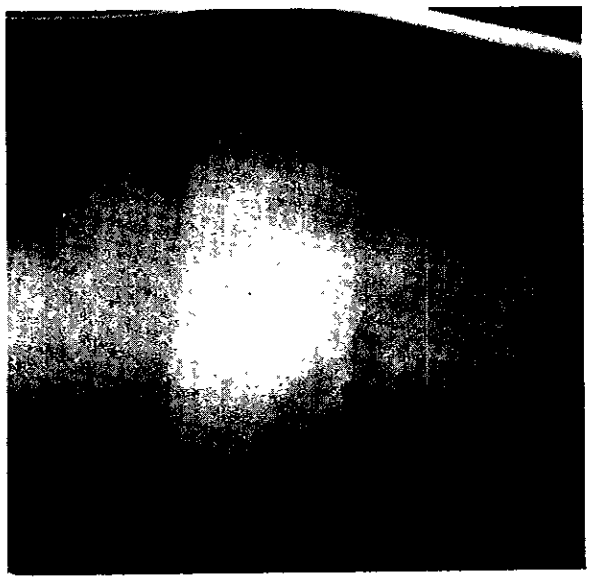
Gamma Radiograph (b)

MODERATE POROSITY

ACCEPTABLE THERMIT WELD



Section Through Weld #17

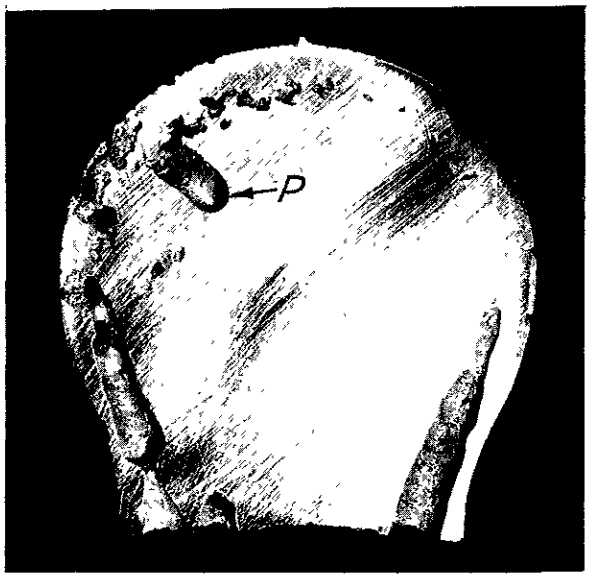


Gamma Radiograph (a)

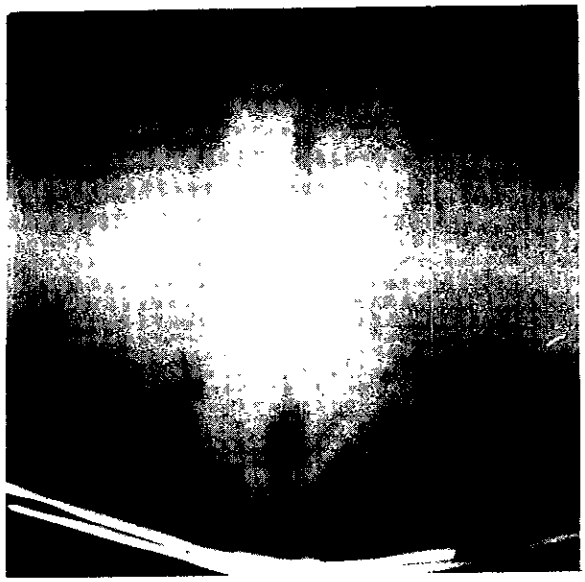
Gamma Radiograph (b)

MEDIUM POROSITY

ACCEPTABLE THERMIT WELD



Section Through Weld #5



Gamma Radiograph (a)

Gamma Radiograph (b)

Maximum porosity permissible around a thermit weld. Note how porosity is outside of the actual weld area and does not interfere significantly with the central cross-section of the weld. This condition is apparent in radiograph (b) which was made through the gate area. The absence of dark areas in the central portion of the weld indicates sound material in that region, excepting for the re-entrant porosity flow shown at point P on the exhibits.